

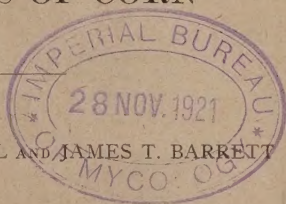
1909

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 133

EAR ROTS OF CORN

By THOMAS J. BURRILL AND JAMES T. BARRETT



URBANA, ILLINOIS, FEBRUARY, 1909

found. In this case infection always begins at the tip and proceeds downward, rarely involving more than half the ear. In both forms badly diseased ears are tightly clasped by the dry, brittle husks except in cases where infection by *Diplodia* takes place in the base of the ears too late in the season for the entire ear to become diseased. Many of the badly diseased ears on account of their lightness in weight remain upright.

The diseased ears shrivel up more or less, become darker in color and lighter in weight. The kernels are also shriveled, are very brittle, and are loosely attached to the more or less rotten cob. The silk is moldy and adheres by the mass of fungous threads to the inner husks and corn. Under the microscope the starch is seen to be variously corroded and notched, and it is frequently discolored. The germ portion of the kernels is most frequently killed, or if not is always injured. Microscopical examination shows that the fungus penetrates all parts of the ear, sometimes extending into and badly injuring the shank. No ill effects on other parts of the corn plant have been observed.

The other *Fusarium* diseases mentioned produce very different effects on the ears and are commonly not detected in the field until the husks are removed. *Fusarium* I. attacks only those husks which come into contact with the diseased surface of the ear. The cob is not so generally diseased as in the above described forms. A third *Fusarium* species, *Fusarium* III., attacks the ends of scattered individual grains, causing them to crack open and the starchy contents to become crumbly. Mycelium and spores are found in this crumbly starch which is considerably corroded. (Pl. III., Fig. I.).

SEASONAL OCCURRENCE

The premature yellowing of the husks on plants otherwise healthy is, as previously stated, an indication that a diseased condition exists which is usually attributable to infection by some one of the field rot organisms. This condition in the case of the *Diplodia* disease may be found in fields soon after the fertilization of the corn has taken place, the number of infected ears increasing more or less thruout the season. Very little is known as to the time of maximum infection by the various species of *Fusarium* which cause these diseases. Two of the forms, as previously stated, can rarely be detected until the corn is husked and the third has not been well studied in the field.

Infection is certainly in the case of *Diplodia* and very probably in that of the other fungi brought about by means of spores. It is known that under favorable conditions *Diplodia* spores are produced in large numbers during the summer and fall in infected fields, and that these spores are carried considerable distances by the wind. They are scattered thruout the fields where they find favorable germinating conditions, and yet the fungus has not been found on any other plant, nor has any other part of growing corn other than the ear and its shank been found to be infected.

The best spore-producing periods seem to follow hot, rainy weather preceded by more or less continued dry spells, the reason for which will be stated later.

Since, then, under favorable conditions the spores are produced in such large numbers thruout the season, the matter of little or much infection depends in part, at least, on these spore-producing periods coming at a time when the corn is in the most susceptible condition for infection. Of a large number of inoculations made during the season of 1907 the highest percentage of infections was obtained from those made on August 31, from a pure culture, when the corn was in the thick-milk stage. It is at this period and later, in the development of the corn, that the larger percent of infected ears in the field begins to show.

**INFLUENCE
OF LOCALITY,
SOIL, ETC.**

These diseases occur with more or less severity in almost every locality in Illinois where corn is grown, and the same or similar ones have been reported from Nebraska, Arkansas, Iowa, Indiana, Ohio, and North Carolina. It is quite probable that no corn-growing section is without at least some of the diseases. Corn grown on the rich, black land of our corn belt is more subject, on the whole, to them than that on higher and thinner soils, although a few seemingly contrary reports have been received.

A part of the report from Vermilion County is as follows:

"The field had about 5 acres of what we call low, black land; this always has the best corn and this year we seemed to find the most rotten corn in this part of the field. There seems to be less rotten [corn] on high ground where plenty of manure had been used. I also noticed in another field containing some of the same black soil that the rotten [corn] is thicker than in any other part of the field. We do not find it this year in quite the same form as last year. You can tell by the looks of the husks if an ear is rotten. Last year many rotten ears had just as bright husks as the good ears and you could not tell until you had husked an ear whether it was good or bad. This year the husks on the rotten ears are black or nearly so."

The following is from a report from Douglas County:

"I farmed a 33-acre field belonging to a man who does not sow clover at all (this piece being in corn about 13 years). And the amount of rot was large, especially on the low ground. I do not know what amount of rot was on the field last year. I notice that as a rule the rotten corn appears to be in spots, say two or more ears near by, especially in proximity to tiles or drains,—our tiles and ditches are not working well in this section at present and the low ground is wet much of the season when we have a good deal of rain. Of course there is some rotten corn on the high ground."

A report from Wayne County states:

"Found a larger percent about the old stockyards and heavily manured spots."

The greater the number of old stalks and the greater the supply of moisture, the better the opportunity for a continual and rapid propagation of the most destructive of these fungi, thus subjecting the corn grown at such a place to a much greater chance of inoculation.

**EARLY AND
LATE PLANTED
CORN**

There seems to be some difference of opinion as to the extent of rot on early and late planted corn. This difference has been, the past two seasons, in favor of the early planted, the majority of the reports stating that it showed more rot. Fifty-five percent said that there was more

rot in the early planted, 33 percent in the late and 12 percent found no perceptible difference. In 1906 a very dry summer was broken by heavy rains while the early corn was beginning to silk. Everything was favorable for the production of *Diplodia* spores, and as a result much corn rotted. Sixty-one percent of all reports for that season stated that the early corn was more badly rotted. Such differences cannot be attributed to differences in susceptibility of early and late corn, only in so far as influenced by weather conditions. Warm, moist weather favors the development of the diseases and the production of spores, and when these conditions obtain at the most susceptible period in the development of the ears everything is favorable for infection. Inoculations made late in the season on corn in the right condition grew much more slowly than earlier ones, due, no doubt, to cool weather.

**ON OLD OR NEW
CORN GROUND**

From careful data collected by the department and from reports sent in by corn growers, it is very apparent that, as a rule, ear rot is more prevalent and destructive in fields planted successively to corn than in those on which a good system of rotation is practiced. There are, of course, exceptions to this, but they are rare. The old stalks and diseased ears when left in the field are known to carry the *Diplodia* fungus over winter, and to offer opportunity for infection the following season.

A report from Fulton County says:

"There was about three times as much rot on the fourth crop of corn on the same ground as on the first."

During the fall of 1907 some field counts were made at husking time as to the relative amounts of the different forms of rot in fields both old and new to corn* on the same farm. The old ground produced the most rot in every case.

Of the reports sent in the past two seasons 65 percent stated that more field rot is found on old corn ground, 16 on the new, and 19 said there was no difference.

Instances are not uncommon where one or more sides of a field for a number of rows are much more affected than the interior, indicating a source of infection without the field. In view of the easy transmission of the spores by the wind, this is entirely possible, and also accounts for the fact that corn on new ground may become badly diseased.

A report from De Witt County says:

"The outside of my fields had more rotten corn than the inside, and the east sides more rotten than the other sides."

In May, 1908, a clover field was visited which produced a crop of corn in 1906 badly damaged with rot. The field was sown to oats and clover in 1907, and in 1908 most of the field planted to corn. Old corn stalks were plentiful in the clover field and most of those examined were abundantly infected with the *Diplodia* fungus. The stalks were not all covered by earth in the portion of the field planted to corn and

* "New to corn," meaning not previously in corn for at least two years.

these, too, carried numerous spores. The latter were found to be capable of germination.

Even though all stalks in the corn field had been covered, there remained abundant opportunity of infection from the clover field. This is but one instance of a condition which is not at all uncommon. The first requisite of an epidemic of disease is the presence of a sufficient number of spores or germs capable of producing it, and their absence is a sure prevention.

A correspondent from Springdale, Arkansas, writing under date of October 10, 1908, remarks:

"Will say that out of 500 ears gathered in a field planted the third straight year in corn, 4% were affected by this trouble."

VARIETIES

No definite data have been collected as to the susceptibility of the various varieties of corn to the rot diseases. Of those mentioning the matter in reports forwarded to us relative to the 1906 crop, 50 percent said yellow and the other 50 percent that white was the most susceptible. The reports of 1907 showed that some form of rot occurred with six different varieties, but few statements as to comparative amounts were made. One who breeds and raises corn for seed reported that the rot was much worse on certain rows growing directly beside others where each row came from a separate seed ear.

AMOUNT OF INJURY

Upon careful observation and inquiry it has been ascertained that the loss is much greater than is ordinarily supposed and sometimes amounts to surprising percentages. In the autumn of 1906 fields were examined by the writers in which as high as 10 percent of the ears were so attacked, and reports of actual counts were received in which as much as 20 percent of rotten ears were recorded. Reports of from 10 percent to 15 percent were not very unusual.

Upon the best estimates that could be made with the aid of hundreds of correspondents in all parts of the state, the conclusion has been reached that in 1906 the destruction from the cause in question amounted to 4.5 percent of the entire crop, and in 1907 to about 2 percent of the produce of the state for that year. When the enormous total of the corn crop of Illinois is considered, the losses reach magnitudes which necessarily arrest attention and imperatively call for investigation.

The State Department of Agriculture reports the corn crops of Illinois in recent years as follows:

1903	264,087,431	bushels, worth \$	95,071,475.
1904	344,133,680	" "	134,212,135.
1905	382,752,063	" "	145,445,784.
1906	347,169,585	" "	124,981,051.

Of the crop for 1906 there were, therefore, lost about 15,622,631 bushels, worth \$5,620,147. There was much less of the rot in 1907, but the loss figured in a similar way from the best data at hand was not less than \$2,000,000. These figures at least indicate enormous

financial damage year by year which has not heretofore been duly appreciated on the part of the farmers or of others interested. While the rots have long been casually known and the variations in proportions of affected ears have often been remarked, there is good reason to suppose that there has been really considerable increase during later years. From the information now gained, further increase is very probable upon land persistently devoted to this crop. The amount for 1906 was undoubtedly far beyond an average; but this may easily be much surpassed some year not now distant, while the general average loss, unless wisely prevented, is pretty sure to increase more or less constantly.

If all this is true for Illinois, the figures for the whole country must reach enormous proportions. While it is probable that there is more absolute loss in Illinois than in any other state, this seems but due to the fact that there is more corn produced and that the best land is more often continuously planted to corn year after year. Certain it is that similar losses are common thruout the area extending from Michigan to Arkansas and from Nebraska to North Carolina, as our own observations and correspondence prove. While so often considered negligible locally, the total loss in the United States must sometimes amount to at least \$25,000,000 in one year.

CAUSES OF EAR ROTS

Most people still suppose that molds are the direct results of the prevailing conditions.* Dampness and confined space are most frequently thought of as the causes of moldiness. When a piece of bread is shut up in a tin box or when placed in a damp cellar, it soon becomes covered with a cobwebby growth soon taking on a characteristic color, as bluish or blackish, and having a musty odor. These molds are plants; there are many kinds of them. They reproduce themselves and grow when once started after the fashion of the higher, better known plants. Instead of seeds they produce spores which differ from seeds in being much more simple in structure and in being too small to be seen singly by the unaided eye. Sometimes, however, they are easily so seen in masses as a cloud of dust arising from a disturbed surface. In fact it is mainly the spores which give to any given mold-crop its characteristic color. They are produced in enormous numbers, absolutely innumerable even from a small area of an infected substance; and it is to this abundance of "fruit" and the microscopic size of the individual spores, permitting easy and wide carriage by the air, that the plants everywhere spring into existence when conditions favor germination and growth. Unlike the higher, green-leaved plants, they do not require light for development. They grow only on organic matter, on food already prepared—in this respect like animals. But

* A correspondent says: "I have never considered the loss of corn by the rotten ears found at husking time due to any other cause than water entering the husk and remaining during a warm day or two which seemed to steam the ear and cause it to shrivel and then decay more or less, as the case might be." Another says: "Mold depends on weather conditions more than anything else." Another, "The prevailing opinion among farmers is that dry weather is the cause of dry rot."

they are really plants, each producing "seed" after its kind from which, and only from which, it continues its existence. Their generations are shorter but they have the same round of germination, growth, fruitage and death as do other living beings. Origination, except in this method, does not occur. No matter how moist the air or how devoid of ventilation the space or how favorable the temperature, a piece of bread never can become moldy, indeed can never decay at all, without a seeding with spores or their substitutes. And no special kind of mold, or other fungous growth can develop, without, to start with, the spores of this particular kind or species.

Molds belong to the great group of plants called fungi—a group including besides molds and mildews, all such diverse kinds of plants as the shelf-fungi on deadwood, puff-balls, mushrooms, toadstools, and a host of microscopic forms among which are the rusts and smuts upon cereals. The greater number of the thousand and more kinds of fungi grow only on dead organic matter. Their function is to induce decay, decomposition, putrefaction, etc. These are called saprophytes. But some are capable of attacking the living bodies of plants or animals. These are called parasites. Again, some of the latter may live, either as saprophytes or parasites, while others are strictly limited to living bodies and often to a particular species, called the host, for each parasite. Thus the large, sooty masses seen on corn stalks or ears is made up of the spores of a special parasite which attacks nothing else than the maize plant, and develops only on this plant during its lifetime. The vegetative portion of the fungus—answering in some sense to the roots, stems, and branches of the higher plants—is called the mycelium. In molds this constitutes a cobwebby, puffy substance which is more often white. The spores (fruit bodies) are borne on the mycelium or upon specially modified structures arising from it. The latter are of wonderfully varied form and structure, while the mycelium itself is characteristically made up of fine filaments or threads with comparatively little difference in form for different species. Under the microscope the spores of each kind are usually recognizable and often are very distinct.

Now the ear rots of maize are due to definite species of mold-like parasites. So far as is known, these grow on nothing but the corn plant, though some of them may have wider possibilities. The greatest amount of destruction is made by one kind called *Diplodia Zeae*. There are numerous species of *Diplodia* known on various hosts or substances, but this one seems to grow only upon maize. It was first found producing its characteristic spores on dead stalks and was then considered a purely saprophytic plant. When in recent years the mold on many living ears was traced to *Diplodia* the suspicion was strong that it was a distinct species, but our investigations have clearly shown that the growth on the green ear and that upon the dead stalks is one and the same thing. This fungus is, therefore, a parasite during a part of its life and a saprophyte at other times.

It is evident now how the fungus lives over from year to year, and how the growing ears gain infection. As will be fully shown

later, the spores are produced in abundance during the summer upon old stalks, even from those lying on the ground the second year, and these spores are readily carried by the wind as dust. Lodging upon the developing ear they germinate when the conditions are favorable. For this moisture is a necessity; temperature has something to do with it. Given the same distribution of viable spores there will still be much seasonal difference in the amount of rot, due to the differences in influencing conditions, without at all supposing that the conditions originate the trouble. The rot could not, does not, occur without the infecting spores, no matter what the weather may be, what the soil may be, or what state soever the corn plant may be in. Conditions simply favor or do not favor the spore growth. With spores capable of germination on the green ears, rot is likely to follow moist weather because this permits the growth of the fungus. Then the state of the corn plant has something to do with it. Undoubtedly a difference exists at different times concerning its power of resistance. It is more susceptible to infection at one period than at another, other things being equal. The maximum of rot will occur when numerous spores of the fungus are deposited on the ears at a time when these are easiest infected and when the weather conditions most favor the fungus in its growth. Much difference may therefore be anticipated in the amount of rot from year to year, due to the coincidence or otherwise of the favoring conditions.

The principal other fungi which have been found as agents of ear rots of corn are species of the genus *Fusarium*. Three of these have been distinguished, to be described later. To the casual observer their effects on corn are identical with the result produced by *Diplodia*, but on closer comparison differences are discoverable. All show mold-like growth. All cause decay of the part of the ear infected—silk, kernels, cob, husks and sometimes shank—causing these parts at length to become dry, brittle, and light in weight.

In addition to these fungi certain bacteria sometimes cause a rot of the developing ears, producing final results somewhat similar to those described. This form does not seem to be very common and has not been much studied. Possibly more than one species thus infest corn ears. Further investigation must be made before much may be known concerning the part played by bacteria in these field rots of maize.

In a word, then, the rots observed upon the ears of corn in the field are due to certain parasitic plants, mold-like in appearance, belonging to the genera *Diplodia* and *Fusarium*, and to one or more species of bacteria. The amount of destruction at any particular time depends upon the varying prevalence of the spores of these parasites in association with conditions existing at the given period. It is worthy of remark that in no case has natural infection by these parasites been discovered upon any other part of the immature corn plant save the ears and their belongings. Upon the latter infection always begins externally from air-distributed spores.

DIPLODIA ZEAE (SCHW.) LÉV.

LIFE HISTORY
ON EARS

The mycelium of the *Diplodia* organism, as it occurs in the active growing condition on the ear and inner husks, is white in color and the much branched threads are about $4\mu^*$ in diameter. With age and more or less drying up of the diseased tissue the size of the newly formed threads become smaller, averaging about 2.5μ . With the exception of a slight darkening in color of portions more exposed to the air and the deep coloring of that which surrounds and goes to form pycnidia (fruit vessels), the color of the mycelium remains white.

The slender threads penetrate the young tissue of the grains, cob, and husks, progressing from cell to cell and extracting from their contents whatever is of value for food. After the ear has become entirely involved or the growth of the parasite somewhat checked by the maturing of the corn, the fungus begins to form its reproductive stage. This consists of small black bodies which develop in the husks, cobs, and more rarely in the grains, and which contain large numbers of purplish brown, rather slender, two-celled spores, $25 \times 5.2\mu$ in size. (Pl. VIII., Fig. 1.). If the outer husks of an ear in a well advanced stage of the disease are pulled down, the spore cases, or pycnidia, will be seen as minute black specks slightly elevated above the surface. (Pl. IV., Fig. 2.). An examination with a hand lens will reveal emerging from the ruptured tissue a short neck which contains a centrally located circular pore through which the spores escape. The pycnidia usually occur singly on the husks, but several grouped together in a mass is not an infrequent thing where conditions have been favorable for a luxuriant development of the fungus, as under bell jar conditions.

The pycnidia which develop in the cob are much more irregular in shape. They develop principally on the scales which surround the inner ends of the corn kernels, hence are usually not detected until the ear is broken, when they are seen forming a concentric ring of black specks about the margin of the cob. (Pl. VII., Fig. 1.). They are usually not at all or only slightly imbedded in the tissue of the cob, but are seated in a rather dense mass of white mycelium from which they originate. A longitudinal section of an ear also reveals them very distinctly. (Pl. III., Fig. 2.).

Diseased ears left in the field under natural conditions eventually develop numerous pycnidia in the grains, giving them a black appearance. In May, 1907, rotten corn of the 1906 crop was scattered over a small plot of ground in an infection experiment. The following March some of this corn was collected and was found as described above. Many of the pycnidia contained spores, some of which were germinated in the laboratory; but most of them were old and empty and at that time all development of the organism had apparently ceased.

The pycnidia formed in the cob, as previously stated, are quite irregular in shape; but those found in the badly diseased grains are somewhat flask-shaped with the comparatively short neck projecting

* A μ is .001 of a millimeter or .0004 inch.

thru the testa. (Pl. X., Fig. 2.). It will be noticed from the figure that the wall of the pycnidium is formed by the interweaving and fusing of the hyphae, or mycelial threads, which form a tangled mass between the seed coats and starchy portion of the grain. The wall of the tubular neck is much thicker than that of the body of the pycnidium and is mostly made up of thick-walled cells, with others having thinner walls lying toward the outside. Arising from the inner surface of the pycnidial wall are numerous simple conidiophores, or spore stalks, on which are borne the two-celled, brown spores. Among these are numerous paraphyses, or stalk-like forms without spores. (Pl. X., Figs. 1 and 2.).

The development of the *Diplodia* fungus is not confined alone to warm summer weather, as is evidenced by an examination of diseased ears in the field during the winter and early spring. January 29, 1908, a stalk of sweet corn with an ear attached enclosed in the husk which had been inoculated with *Diplodia* spores on August 10, 1907, was brought into the laboratory from the field where it had been all winter, and at the time was partially covered with snow and ice. On removing the husks a mass of white mycelium in an active condition was revealed. Pycnidia were present in various stages of development and the spores germinated readily. On March 6, 1908, some diseased ears of field corn in husks on stalks left in the field in the fall of 1907, were examined and were found to be in much the same condition as was the ear of sweet corn just described.

ON STALKS

The first indication of the *Diplodia* fungus on the dead stalks is the appearance of very small dark colored specks under the rind. In outdoor conditions these may appear during late fall and winter but usually develop during the spring and summer. An examination of stalks in the field on March 6, 1908, revealed very few that showed any developing pycnidia, but in the same field and plat on May 14, 1908, many stalks showed numerous developing spore cases just beneath the rind, few having broken thru. (Pl. VI., Fig. 1.). The stalks had been dragged and broken off near the ground and most of the fertile portions were at or near the breaks. The pycnidia are produced all over the old stalks but are usually more abundant about the nodes. This condition is more frequently found in two or more year old stalks. There is also a tendency for them to occur in vertical rows. During the summer the necks of the pycnidia begin to break through the rind of the stalks and in favorable weather conditions send out large numbers of spores. Pieces of diseased stalks one or two years old have been found in July, August, and September almost covered with black tendrils of *Diplodia* spores capable of quick germination. Apparently the spores are slightly coated with a gelatinous substance, as in a protected place they adhere together in tendrils for some time, but immediately separate on the addition of water. (Pl. VI., Figs. 2 and 3.). Pieces of stalks almost three years old have been found bearing pycnidia and some few of the spores found in them were capable of germination. These were pretty badly decayed, however, and the fungus was not in a very active condition.

This fungus has not been found growing naturally on the green stalks, although, as will be further mentioned, a slight growth was produced by artificial inoculation. The green shanks, on the other hand, are frequently found badly infected when bearing diseased ears.

Old stalks may become infected, thru diseased ears and shanks left on them in the field, after they are matured and dead. As in the ears, there seems to be some growth of the fungus in the stalks in rather severe weather conditions. Many stalks are no doubt infected in the late fall, the fungus slowly spreading thru them and with the advent of spring weather developing its numerous pycnidia and spores. Just how long the spores may retain their vitality in the pycnidia after being formed is not known, but that they will germinate after remaining thus for six months is shown by the following experiment. During August, 1907, some infected pieces of old cornstalks were brought into the laboratory and kept in a very dry place during the winter. These were examined from time to time and there was no appearance of any young pycnidia. Most of the old ones were filled with spores. On February 25, 1908, some pieces of these stalks were soaked over night in water and then placed in a moist chamber. After a few days long tendrils of *Diplodia* spores covered the surfaces of the stalks. (Pl. VI., Figs. 1, 2, and 3.). The figures show one soaked and one unsoaked piece from the same stalk. A large percent of these spores were capable of germination. After remaining a few days longer in the moist chamber these pieces of stalks were washed with a small brush, removing all spores, and again allowed to soak in water for a few hours. They were then returned to the moist chamber with a new piece of the same stalk soaked for the first time. The latter piece was in a few days covered with the spore tendrils, but all others even after weeks showed no sign of exuding spores from old marked pycnidia. A few new ones finally developed which produced spores. Sections made of the old pycnidia revealed only a few, mostly collapsed spores which evidently failed to get out with the others. This experiment together with other observations leads to the supposition and strong probability that pycnidia soon reach a mature stage after which no more spores are produced. This explains the occurrence of so many tendrils of spores on old stalks after rains following dry weather. During the dry period the pycnidia come to maturity and are filled with spores. As has been seen, moisture causes the expulsion of the spores and their abundant appearance after rains. If the season is rather moist thru-out, the issue of spores is more evenly distributed, and danger is then less than when large production occurs when the corn is most susceptible.

Pycnidia produced on corn stalks are fairly regular in size and structure and usually occur singly. Sometimes partitions separate the interior into two or more chambers which emit their spores through a common opening. Occasionally one may find several pycnidia congregated together without the presence of a stroma, but this is rare on the stalks. Many are vertically compressed and most of them have a thicker wall than those found on the corn grains and in cultures. (Pl.

X., Fig. 1.). It will be noted from the figure that the wall of a Pycnidium is made up of two fairly well marked layers of tissue, an outer, composed of rather thick walled threads taking on the nature of cells by the short joints, and an inner one made of thinner walled cells which form a hymenium or fruiting layer.

Arising from this layer are seen numerous sporophores and paraphyses. The spores become two-celled before leaving the pycnidium. Howard* states that in the case of *Diplodia cacaoicola*, the spores at the time of leaving the pycnidium are greyish and unicellular but that they soon become dark brown, the septum appearing at the same time.

The mycelium in the stalks is mostly hyalin, becoming somewhat dark about the pycnidia. The beginning of a pycnidium can be seen in section just under the rind as a rather closely matted and much branched mass of brownish colored threads which finally becomes almost black in appearance. The threads of the mycelium penetrate the cells of the pith and partially fill them and make their way in the woody portions from one element to another by means of the pores. (Pl. X., Fig. 1.). In some cases one can trace the disease in the pith by a slight darkening of that tissue, but this is not an infallible sign of its presence.

The protoplasm of the mycelial threads in the active, growing condition is slightly granular and sometimes very much vacuolated, but in the older and more matured condition the threads are more or less filled with oil globules.

GROWTH IN CULTURE

A large number of cultures were made on various natural and artificial media with the hope of inducing the fungus to develop a perithecial stage, but all attempts to find such, either in culture or in nature, have been without success. Perhaps this stage has been entirely lost from the life history of the fungus or it may be that the conditions necessary for its formation were not found. Although many cultures were made directly from diseased tissue, all comparative cultures were descendants from a single spore.

The fungus grows very well on many fruit, vegetable, and artificial media, the amount of mycelium and number of pycnidia varying considerably. Both solid and liquid cultures were modified in various ways as to their reaction and the nature of the carbohydrate present, with some striking results.

The media used most extensively for propagating spores for inoculation work and for maintaining a stock of pure cultures was boiled rice in tubes in the proportion of 2 grams of rice to 8 cc of distilled water. This induced a rapid growth and an abundant formation of pycnidia and spores.

A series of 20 tubes containing boiled vegetables, grains, and nuts were inoculated and the resulting growths compared. A number of them proved excellent for the development of mycelium but few were suited for production of spores. Notes are given as follows:

* Howard, Albert. On the *Diplodia cacaoicola*, P. Henn. A parasitic Fungus on sugar cane and cacao in the West Indies. *Annals of Botany* 15: 686, 1901.

Boiled turnip.—A rather dense, white growth, becoming grayish with age and covering and surrounding most of the slant. No pycnidia developed.

Boiled carrot.—Good, rather flocculent growth surrounded the slant. Pycnidia rather sparse.

Boiled salsify.—A very fair growth developed after two weeks or more, but no pycnidia were produced.

Boiled parsnip.—Excellent growth of white, rather cottony mycelium surrounded the slant. A slight tinge of brown appeared. A good many pycnidia were developed.

Boiled potato.—Fair, rather compact growth all about the slant; cream to light brown with age. No pycnidia formed.

Boiled beet.—Growth pretty fair; but mycelium and liquid at the bottom of the tube very brown. No pycnidia found.

Boiled apple.—Growth pure white and very slow, becoming fair in six weeks.

Boiled macaroni.—Growth pretty good; white tinged with gray to light brown in patches. A good many small pycnidia formed.

Boiled cabbage.—Growth poor. No pycnidia.

Boiled orange.—Growth good; white, becoming somewhat gray with age. A very few small pycnidia developed.

Boiled onion.—Growth good; mostly white. Pycnidia rather abundant.

Boiled Brazil nuts.—Growth fair; mycelium tinged light brown. No pycnidia.

Boiled cocoanut.—Rather good growth, turning to dirty cream, almost light brown at the lower portion. No pycnidia developed.

Boiled peanuts.—Fair growth developed; white above, becoming light brown with age. No pycnidia.

Boiled green bean stems.—Growth fair. No pycnidia.

Boiled germinated corn.—Growth good, filling spaces between the grains. Very few pycnidia.

Boiled soaked corn.—Growth good; white becoming slightly darkened with age. Pycnidia rather numerous.

Boiled corn.—Growth much like that of the boiled soaked corn with more pycnidia present.

Cocoanut milk agar.—Good growth. A good many pycnidia developed.

Litmus lactose agar (acid).—Growth fair, agar changed to blue at top, becoming brownish later. Pycnidia absent.

Five cultures were made in liquid media with *Diplodia* spores from a pure culture.

Uschinsky's fluid*.—In one week a thin flocculent growth was present thruout the liquid—and a week later most of the growth was within 1 cm of the surface which was covered by a thin growth. A sparse growth of mycelium had extended 8 to 10 mm up the sides of the tube. The growth finally became slightly more dense, showed a tinge of brown at one place, and produced a few pycnidia at the surface on the sides of the tube.

Raulin's fluid†.—In one week a thin white growth covered the surface of the liquid and extended 6 mm up the sides of the tube. A slight submerged growth was present near the surface. One week later a dense growth covered the surface and the submerged portion for 3 or 4 mm deep had a beautiful green color. The aerial portion on the sides of the tube showed alternate zones of light cream, pink, and brown. Later the growth and the intensity of the colors increased. The bright green finally became a dirty green and then almost black. A few pycnidia were produced.

* Uschinsky's fluid.—Distilled water, 500 cc; glycerin, 15 cc; ammonium lactate, 3 cc; sodium chlorid, 1.5 grams; sodium asparaginate, 1.5 grams; dipotassium phosphate, 1 gram; calcium chlorid, 0.05 gram; magnesium sulfate, 0.05 gram.

† Raulin's fluid.—Distilled water, 1,500 cc; cane sugar, granulated, 70 grams; tartaric acid, 4 grams; ammonium nitrate, 4 grams; ammonium phosphate, 0.60 gram; potassium carbonate, 0.60 gram; magnesium carbonate, 0.40 gram; ammonium sulfate, 0.25 gram; zinc sulfate, 0.07 gram; ferrous sulfate, 0.07 gram; and potassium silicate, 0.07 gram.

Beef bouillon.—In a week's time a slight growth had developed thruout the liquid and a rather dense layer of white mycelium covered the surface. In two weeks the growth had become more dense on the surface, extending up the sides of the tube 6 to 8 mm and thruout the liquid as a light flocculent cloud. The growth remained white and but 2 pycnidia were found.

In a solution containing 2 percent of Witte's peptone, 1 percent dextrose, 1 percent maltose, and 1 percent mannite, a very dense growth had covered the surface of the liquid and a flocculent mass developed all thru it in one week. Growth increased rather rapidly, becoming more dense on the surface and extending well up on the sides of the tube; color white, finally becoming tinged with brown in a few places. The liquid below the growth became deep orange in color. Only a few pycnidia were produced.

Distilled water with 2 percent of Witte's peptone and 1 percent glycerin:— In one week the surface was only partially covered with mycelium and but little could be seen thruout the liquid. One week later growth was good, a dense white mass covering the surface but not extending far up on the sides of the tube. Slight growth in the liquid. Very few pycnidia were formed.

EFFECTS OF ACID AND ALKALIN MEDIA

Three series of cultures were made relative to the effects of acid and alkali on the growth and fruiting of the fungus. A number of both organic and inorganic acids were used in the two acid series and one alkali, sodium carbonate, in the alkaline series. The medium used in all tube cultures was boiled rice, and in plate cultures it was extract of corn meal with agar.

The injurious effect of the alkali was very apparent in cultures containing very small amounts as three parts of a normal solution to one thousand of media gave no growth, while slightly less amounts produced a very weak mycelium and few pycnidia. It should be said that boiling rice in the presence of alkali reduces the alkali proportionally to the amount present, and it was found necessary to prepare an extra series of tubes for titration after sterilization in order to be sure of the reaction of the media when inoculated.

As a result of the cultures in acid media it was found that of the organic acids used the most injurious were formic and butyric, members of the acetic series, while the best growth and greatest development of pycnidia took place in the presence of oxalic, malic, citric, and tartaric, members of the hydroxy acid group. At the strength of twenty-five parts normal acid to one thousand of media no growth took place in the presence of formic and butyric acids, while in the presence of acetic, a member of the same group, there was a pretty fair growth of mycelium tho very few pycnidia. This applies also to the growth in tartaric and lactic acid cultures. Of the inorganic acids used, hydrochloric, nitric, and sulfuric, the first two were most favorable for good development of mycelium, while nitric alone seemed to be favorable for the formation of many pycnidia, there being very few to develop in either of the other two cultures. Variation of color appeared in some of the tubes. In the malic acid culture patches of cream, yellow and orange to brown were present. Similar colors, but less marked, appeared in the acetic and citric acid tubes, while that in all others was principally white tinged with cream to gray.

A series of cultures was made in poured plates for determining the effects of the acids, alkalis, carbohydrates, and a few other substances

on the production of pycnidia. The media to which almost all the above were added was extract of corn meal with agar. All acid cultures were made a strength of +20, Fuller's scale, and those containing alkali—15, same scale.* All carbohydrates except starch were used 5 percent strength.

In two weeks the following condition existed in the plates:

Formic, acetic, butyric, and oxalic cultures had developed no growth, while the colonies in those containing malic, tartaric, citric, and lactic acids covered the surface of the plate and extended well up the sides with zonation clearly shown. The growth in standard agar and standard gelatin was rather dense and covered most of the plate. No zonation was present. In the cultures containing glucose, galactose, maltose, and cane sugar the growth was rather dense, especially at the margin and on the sides of the plate which was entirely covered. In litmus-lactose agar, Uschinsky's solution hardened with 2 percent starch, and Fermi's solution† agar the growth was rather poor, particularly in the last named medium where only a small, thin colony developed. The growth in the plates containing sodium and potassium hydroxids was very thin, irregular, and almost entirely submerged.

In one week there was in a few cultures—those containing glucose; galactose, and maltose—an indication of forming pycnidia. They rapidly increased in another week and at the end of the third week about all had formed that did appear. None developed in standard agar, standard gelatin, Fermi's solution agar, potassium hydroxid, and litmus-lactose agar; very few in malic and tartaric acid cultures, and only about 50 and 75 in those containing citric and lactic acids. Three developed in the sodium hydroxid culture and about 40 in Uschinsky's solution plus starch. In the check plate which contained extract of corn meal with agar the number of pycnidia was fairly large. The cultures producing by far the most pycnidia were those containing the sugars in the order of maltose, galactose, cane sugar, and glucose. Over 200 were counted in one square inch of surface. Plate IX., Fig. 1 is a photograph of the galactose culture.

It will be noticed that most of the pycnidia develop near the margin of the plate. If only a very few formed they were almost invariably on the sides of the plate or at the very margin.

By means of the microscope the beginning of the pycnidia can be seen in plate cultures as a small clump of irregularly branched and darkened hyphae which grow in size quite rapidly with an increase in color. Many of them are entirely submerged, form little or no neck, and discharge their spores into the medium thru a more or less broad opening in the wall. It is not unusual, however, to find perfectly formed pycnidia in such cultures but as a rule the necks are shorter than those on the corn stalks. Here, as on the corn husks and occasionally on the stalks, may be found pycnidia with the internal

* That is, plus or minus so many cc of normal sodium hydrate to bring one litre of medium to the phenolphthalein neutral point.

† Fermi's culture fluid is made as follows: Distilled water, 1,000 cc; magnesium sulfate, .2 gram; acid potassium phosphate, 1. gram; ammonium phosphate, 10 grams; glycerin, 45 grams.

cavity divided by partitions forming somewhat irregular compartments communicating with each other toward the orifice. Sometimes more than one orifice is present.

A number of spores from seven of the above cultures were measured and the averages taken. The greatest variation was in the length, the width being almost constant. The largest were in the check plate, the extract of corn meal with agar, and measured $28.5 \times 5\mu$ and the smallest were produced in the same media plus lactic acid and measured $22.1 \times 5.2\mu$.

GERMINATION OF SPORES

Mature spores germinate in from 5 to 8 hours by sending out a hyalin hypha from one or both of the cells which soon forms septa and branches. (Pl. XI., Fig. 3 and Pl. VII., Fig. 2). The protoplasm of the germ tubes is at first finely granular, but as they begin to grow more rapidly it becomes vacuolated.

Almost all germinations were made in Van Tieghem cells three-fourths inch in diameter, using various liquid media and spores from different sources depending upon the nature of the test. Within three or four days a tangled skein of mycelium forms and fusion of hyphae is not uncommon. There may be seen here and there small dark specks, the beginning of pycnidia. Cell cultures offer a good means of studying the first processes in such formations which usually start with hyphae in direct contact with the cover glass. These first send out short, thickened branches which become gradually darkened and usually contain a small, circular, light spot. (Pl. XI., Fig. 4). They increase in number and complexity until a sort of cellular tissue results as has already been described.

In Uschinsky's fluid no germination had taken place in 5 hours; two-fifths of the spores had germinated in 9 hours, and nine-tenths in 70 hours, at which time the hyphae were considerably branched.

In Raulin's fluid about 8 percent were germinating in 70 hours. The germ tubes were short and unbranched.

One-third of the spores had germinated in beef bouillon within 9 hours, three-fourths in 22 hours, and practically all in 70 hours. Pycnidia had begun to form in several places.

In a solution containing 2 percent of Witte's peptone, 1 percent dextrose, 1 percent maltose, and 1 percent mannite, germination began in 5 hours; in 9 hours about half, and in 70 hours nearly all had germinated. Pycnidial formations had begun.

In a solution containing 2 percent of Witte's peptone, and 1 percent of glycerin only a few spores had germinated in 9 hours. In 22 hours about one-third had germinated.

No germination took place in distilled water.

The following tests were made January 1, 1908, to determine the viability of spores of different ages. Seven cultures were made in corn meal extract with spores from the following sources:

- No. 1. Boiled rice tube culture 19 days old.
- No. 2. Boiled rice tube culture 51 days old.

No. 3. Surface of pieces of husk which had been in a test tube almost 5 months.

No. 4. A diseased ear of corn of the 1907 crop, which had been in the laboratory about 3 weeks.

No. 5. An old corn stalk brought into the laboratory November 15, 1907.

No. 6. A specimen of corn sent to the laboratory in March, 1907.

No. 7. Corn specimens collected January 1, 1907.

The results are shown by the figures tabulated below:

Date	No.	Medium	Started	Percent germinated in				
				5 hrs.	22 hrs.	30 hrs.	46 hrs.	64 hrs.
Jan. 27	1	cornmeal extract	11:30 a. m.	60	90	95	95	95
"	2	"	"	10	90	90	95	95
"	3	"	"	0	1	1	1	1
"	4	"	"	8	33	40	40	45
"	5	"	"	0	40	43	45	45
"	6	"	"	0	0	0	0	0
"	7	"	"	0	0	0	0	0

January 29, 1908, *Diplodia* spores were taken from an old piece of corn stalk which had been lying outside the building and exposed to the weather since August, 1908, and sown in corn meal extract in a Van Tieghem cell. In 48 hours 10 to 12 percent, and in 96 hours 15 percent had germinated.

On February 3, four cell cultures were made with *Diplodia* spores from pieces of old diseased corn stalks which had been in the laboratory since August, 1907, and which 5 days previous had been soaked 24 hours in water and then placed in a moist chamber where they produced numerous tendrils of spores some of which were used in the test. The medium used was corn meal extract and the temperature was 26° C. to 28° C.

In 5 hours No. 1 showed a germination of 80 percent; No. 2, 85 percent; No. 3, 92 percent; and No. 4, 90 percent. In 23 hours No. 1 had germinated 95 percent; No. 2 about 95 percent; and No. 4, 92 percent.

DISTRIBUTION OF SPORES BY WIND

The field in which this experiment was carried on is situated on a rather high knoll on the University south farm. In 1906 it produced a crop of corn, 60 bushels per acre, 10 percent of which was destroyed by rot. The stalks were not cut nor were they pastured. In July, 1907, the south half of the field was sowed to cow peas, the north half having been seeded to clover earlier in the season. Numerous pieces of old corn stalks, some at least two years old, were scattered about on the surface of the ground and, being more or less protected by the growing cow peas, were producing in many cases an abundance of *Diplodia* spores. Early in September the cow peas were cut and oats were sowed as a cover crop to the young apple trees to which the field was planted.

On September 17, three stakes were set up in the field, one on the north edge of the recently plowed south half, and the other two toward

the north edge of the clover field. The entire field was about 25 rods wide. To each of these stakes, $5\frac{1}{2}$ feet long and driven 8 to 10 inches into the ground, were fastened 2 glass plates $6\frac{1}{2} \times 8\frac{1}{2}$ inches, one at the top, the other 2 feet below. The plates which faced northeast and southwest were smeared on both sides with glycerin and alcohol. The surface of the ground was rather dry and a brisk wind was blowing from the southwest. After 48 hours the glass plates were removed and new ones similarly treated put in their places. The glycerin and contents was washed from the sides of each plate into separate watch glasses with 95 percent alcohol, and after considerable evaporation the spores were counted. It is quite probable that many of the spores were not washed from the plate by this method and that the results shown below, although strongly convincing, represent only part of the true condition.

Stake No. 1. On plowed ground.	Upper plate, 65 <i>Diplodia</i> spores. Lower plate, 400 (approximately) spores.
Stake No. 2. About the middle of clover field.	Upper plate, 50 spores. Lower plate, 75 spores.
Stake No. 3. North side of clover field.	Upper plate, 40 spores. Lower plate, about 40 spores.

The second set of plates placed on the stakes were not considered further, but on October 1, 1907, 4 microscopic object slides, 3 inches long by 1 inch wide, were placed on two of the above mentioned stakes, two on each, and the south surface of each smeared with glycerin and alcohol. These could be examined under the microscope directly and more accurate results could be obtained.

After 3 days, during which time a hard rain occurred, the slides were removed and a new set substituted, two on each of the three stakes. The count on the 4 slides was as follows:

Stake No. 1.	Upper slide, 25 spores. Lower slide, 33 spores.
Stake No. 2.	Upper slide, 2 spores. Lower slide, 9 spores.

On October 5, after remaining on the stake 24 hours the 6 microscopic slides were removed and the counts made. They were as follows:

Stake No. 1.	Upper slide, 24 spores. Lower slide, 36 spores.
Stake No. 2.	Upper slide, 22 spores. Lower slide, 250 spores. A tendril was present.
Stake No. 3.	Upper slide, 8 spores. Lower slide, 26 spores.

The following experiment was made to test whether the *Diplodia* spores could be caught from the air at some considerable distances from the infected field. Adjacent to this field on the north is a golf field which offered an excellent opportunity for making such a test as it was very clean and free from trash, and one could feel quite certain that most of the spores obtained must have come from the field above mentioned. There was a field of corn to the west of the golf field but the stakes were kept at least as far from it as from the infected

field to the south. Stake No. 1, bearing two glass object slides, was set up in the golf field 50 yards north of the north edge of the clover field with the smeared side of the glass slides facing the south.

Stake No. 2 was similarly set up 75 yards from the same field, but on slightly higher ground.

Stake No. 3 was put 150 yards away. This experiment was started October 10, 1907.

After 4 days, October 14, the above mentioned slides were removed and the counts made. They were as follows:

Stake No. 1, 50 yards from infected field	Upper slide, 28 spores. Lower slide, 37 spores.
Stake No. 2, 75 yards from infected field	Upper slide, 11 spores. Lower slide, 6 spores.
Stake No. 3, 150 yards from infected field	Upper slide, 38 spores. Lower slide, 47 spores.

On October 18 at 8 a. m., the above experiment was repeated by using greater distances in the same field. Stake No. 1 was placed 150 yards, No. 2, 250 yards, and No. 3, 350 yards from the infected field. In addition to the two glass slides used on each stake as stated above, a third was placed at the top of each stake facing the corn field to the west. This field was the same distance from each stake—about 150 yards. All surfaces of the slides facing the south and west were smeared with glycerin and alcohol.

The test continued 4 days during which time no rain fell. On October 22, the slides were removed and sometime later the count was made, the slides in the meantime being carefully protected. The resulting count was as follows:

Stake No. 1—150 yds.	Slide 1 facing corn field,	11 spores.
	Slide 2 facing infected field,	12 spores.
	Slide 3 facing infected field,	6 spores.
Stake No. 2—250 yds.	Slide 1 facing corn field,	4 spores.
	Slide 2 facing infected field,	5 spores.
	Slide 3 facing infected field,	7 spores.
Stake No. 3—350 yds.	Slide 1 facing corn field,	5 spores.
	Slide 2 facing infected field,	6 spores.
	Slide 3 facing infected field,	14 spores.

These results entirely confirmed the supposition of the transmission of *Diplodia* spores by the wind and furnished the means for the explanation of several peculiar things in reference to the distribution of the disease.

INOCULATION EXPERIMENTS

It was now desired to perform some infection experiments having been cut off from the sporophore. In Uschinsky's fluid 90 percent germinated in 24 hours and inoculations were made as follows:

1. On sweet corn.

a. On August 10, 1907, a number of well selected ears whose silk was just beginning to dry were inoculated with spores from a rice tube culture forty days old, by inserting the spores under the outer husk at the base of the ear in some cases, and in others by placing them

well down into the silk at the tip. The same thing was carried out in duplicate using exuded spores from an old diseased corn stalk.

Within five or six days the success of the infections was apparent from the small but striking spots of pale yellowish green that appeared. These increased rapidly in size, changing to the characteristic brown color along the margins. The disease in the majority of cases progressed somewhat more rapidly in the ears inoculated at the base but no apparent difference could be detected in the final effect. Those inoculated with spores from pure cultures were in appearance in no way unlike those that were inoculated with spores from the old stalks, the disease in all progressing at the same rate and showing the same symptoms. On August 27, seventeen days after inoculation, pycnidia could be seen developing on some of the ears. From this time on the ears proper, kernels and cob, became rapidly involved and more or less covered with the white mycelium.

September 3, a stalk bearing two diseased ears was cut and after remaining in the laboratory seven days the upper of the two ears was photographed. (Pl. IV., Fig. 2). The great number of pycnidia can be seen as black masses towards the base of each ear.

b. On August 19 some ears of sweet corn in the same plot as above were sprayed with spores in suspension and others were inoculated by inserting spores in the shank a few inches below the base of the ear. Three of the sprayed ears developed rot, 7 did not, while but 1 of the 10 inoculated in the shank was successful. (Pl. IV., Fig. 1).

2. On field corn.

At intervals from August 14, 1908, to September 13, 1908, inoculations were made in ears, shanks, and stalks of field corn with spores from both pure cultures and old diseased stalks. Ears were inoculated in the silk, at the base, and by spraying them with a suspension of spores in water. Spores were inserted into wounds made in the stalks in different places by means of a knife or needle after which a few drops of distilled water were added.

At the beginning of the experiment the corn was just silking out well and showed no signs of drying whatever, while on September 13, the date when the last inoculations were made, some of the husks showed signs of maturing and the grains were already quite firm. From 40 to 60 ears were used for each method of inoculation and a similar number were always left as checks.

Of all the inoculations made the most successful in all the series were those with spores placed in the silk and under the outer husk at the base of the ears, the former giving a higher percent of successful inoculations than the latter.

Of those inoculated August 14 from a pure culture, 16 percent of those receiving spores in the base were successful, while 59 percent of the silk inoculations developed typical cases of the disease. The percents of diseased ears resulting from the other methods were small; 3.3 from spraying, 3.1 from inoculations made in the stalk just below the attachment of the shank, and 1.5 percent from the checks.

The percent of disease was lower in all cases when spores from exuded tendrils on old stalks were used. Of those inoculated on August 16 with such spores the results were as follows: In the silk 27 percent, in the base 14, by spraying 3.6, and in the stalks 1.8 percent, which last was just about the same amount of disease as developed in the checks.

The highest percents of diseased ears obtained were the result of inoculations made on August 31, as previously stated, when the corn was still in the thick-milk stage. 80 percent of silk-inoculated ears produced the disease, 71.7 percent of those inoculated at the base and 48 percent so treated in the shanks were successful, while but 22 percent of the sprayed ears showed any signs of infection. All later inoculations altho fairly successful produced smaller percents of the disease than the others.

Microscopical examination of the tissue of inoculated stalks showed some development, mostly slight, in a number of cases. In one case the pith was browned below and above the wound, together a distance of three feet, and tubes of boiled rice inoculated with bits of the tissue developed the *Diplodia* fungus. There was no direct evidence obtained that the infected ears on such stalks were a result of the inoculations made.

A number of inoculations made on stalks and leaf sheaths by merely applying spores to the uninjured surface of each and in slight wounds made by scratching with a needle were entirely unsuccessful.

INOCULATIONS On September 5, 1907, several stalks of sorghum
IN OTHER PLANTS were inoculated about two feet from the ground with *Diplodia* spores in wounds made with a pen knife. Five weeks later the stalks were harvested, split open and examinations made. In most cases there was about the wound in the pith signs of infection. The tissue had a deep purplish red color and fermentive odor was evident. Mycelium of some kind was present in all cases but there was no assurance as to its being of the *Diplodia* fungus. The discoloration in one specimen extended about 14 inches above and 3 inches below the point of infection. With pieces of this diseased tissue 2 tubes of boiled rice were inoculated, one piece from near the wound and the other from the portion farthest away. Both tubes developed impure cultures of the *Diplodia* fungus and pycnidia were produced. Of the several other plants inoculated none became infected.

SPECIES OF FUSARIUM.

The species of *Fusarium* found upon developing ears of corn seem to be undescribed, notwithstanding the number of forms which have from time to time been described, and the very considerable attention that has recently been given to the group on the part of plant pathologists and other botanists. There are evidently three different kinds on corn which are sufficiently distinct to be considered separate species. One of these has been studied at length and the others enough to permit the descriptions which follow below. It has not been considered

best, however, to give names to these fungi in this publication, but simply refer to them by number. They are therefore designated *Fusarium I.*, *Fusarium II.*, and *Fusarium III.* It should be said that the field loss by all these does not appear to amount to more than about 9 percent of that due to *Diplodia*, tho they are parasites in the same sense as the latter. They do cause, independently of the *Diplodia* fungus and of each other, a variable percentage of the destruction witnessed.

Fusarium I.

ON THE EARS As the fungus grows on the ears of corn it usually produces a rather dense, felted mass of white mycelium which extends between the kernels to the cob causing it to become more or less diseased. (Pl. II., Fig. 1). The threads of the mycelium can be detected microscopically all through the diseased grains, corroding the starch and destroying the germs.

In the earlier stages of development on the ears the oval or pear shaped spores are rare but in the old advanced cases they are more or less numerous. Two types of spores are produced, microconidia, small, obovate, single-celled spores, and macroconidia, larger, two to four celled ones. The latter are not commonly found in large numbers on the ears or in culture. In but one case were they found in sufficient abundance to produce a pink color and then on a dried embryo ear (that is, an undeveloped branch or ear generally found in the leaf-sheath next below that from which the principal ear issues) which had been destroyed by the fungus. (Pl. XI., Fig. 15). Some of both forms as taken from an ear of corn are seen in Plate XI., Figure 12.

ON THE STALKS Very little is known as to the life history of the fungus on corn stalks. That it does occur there is certain from the fact that a culture made in a tube of boiled rice with discolored pith from a stalk near a node gave an almost pure culture of the fungus. It has been found causing rots of embryo ears and doubtless the mycelium penetrates the stalk as a result, as in the above mentioned case.

APPEARANCE IN CULTURE In culture the fungus shows a vigorous vegetative activity and develops a large amount of a white, rather dense mycelium on most suitable media.

On a plate of asparagin-glucose agar, a centrally located colony grew to be 25 inches in diameter in less than 4 days—the amount of aerial growth increasing with age until scarcity of moisture checked it. The amount of such growth depends greatly on the moisture content of the air as is seen in tubes of rice with various amounts of water present. Under favorable conditions it will grow to a height of 20 mm above the surface of the media.

The mycelium is made up of large and small filaments interwoven and frequently much coalesced, the latter depending largely on the kind of media used, and when occurring to any considerable extent the growth has a stringy or ropy appearance. The large filaments are a

sign of vigorous, active growth and vary in size from 6 to 10μ in diameter. Lack of moisture in a culture aids in bringing about the formation of the small type of hyphae and a production of conidia. These small filaments vary in size from 2 to 4μ in diameter and hence are small in comparison with the larger ones.

In a young culture the hyphae are usually filled with granular protoplasm, becoming during the growing period very much vacuolated. In certain old cultures with the ceasing of the vegetative activities, especially on a very starchy media, the minute fatty drops, which give the granular or turbid appearance to the protoplasm during the active growing period, seem to collect into large, strongly refringent drops and occupy the greater part of the cells.

As seen under the microscope, the microconidia are colorless, obovate to pyriform, and vary in size, sometimes considerably, with the media used. They are produced terminally on simple or much branched sporophores. (Pl. XI., Fig. 13). The end of a terminal hypha, or more frequently a lateral branch, is cut off from the remaining portion by a rather narrow constriction. One after another is thus formed until a clump of spores surrounds the tip of the branch.

The macroconidia vary much in form and size, ranging from $10-25 \times 4-8\mu$, the average being about $18-22 \times 5-6\mu$. They are usually slightly curved and somewhat constricted at the septa. (Pl. XI., Fig. 15). In cultures they are usually rounded at the distal end and taper toward the bluntly acute, proximal end.

This type of spore is formed in culture in very much the same way as the smaller form and sometimes on the same hypha. This was observed in both prune juice and Uschinsky's fluid. (Pl. XI., Fig. 16). So far as observations in this connection could be made the sporophores producing the large and small spores are little if any different in appearance. In both cases there is a slightly swollen portion in the middle of the branch and a slight constriction at the point of attachment to the mycelial filament.

GERMINATION OF SPORES

Both types of spores germinate very readily in many different nutrient solutions. In standard beef bouillon germination began in 3 hours, and 2 hours later one-third of the spores produced germ tubes. In 9 hours all had produced hyalin germ tubes, some of which were quite long. In 22 hours many interwoven branches had formed. At the end of 48 hours no spores had formed.

Other tests were made in Raulin's fluid, Uschinsky's fluid, combinations of Witte's peptone, glycerin, etc., prune juice, and distilled water. Raulin's fluid induced fair germination, but little growth of the hyphae took place. Prune juice proved a rather favorable medium but not so good as Uschinsky's fluid. In this solution germination was very good but the germ tubes never became very long. In 48 hours both kinds of spores were being produced. In no other medium were the large type of spores produced in such abundance. In distilled water both germination and growth were poor.

**GROWTH ON
VARIOUS MEDIA**

The fact that a few cases are on record of inducing the formation of perithecia from the conidial fructification of some Hypocreaceous fungi led to the modification of media, both natural and synthetic, in various ways in an attempt to find such a stage in the life history of this organism. However, no indication of perithecia or any other form of fruit than those described developed.

The fungus grows well on many fruit, vegetable, and grain media made by boiling in certain amounts of distilled water. At all times this organism was distinguishable from other *Fusariums* studied by the large amount of at first pure white mycelium. On sweet potato, carrot, salsify, parsnip, and rice, the growth rises 15 to 20 mm above the surface of the medium in a few days. Poor growths take place on apple, raw potato, tapioca, prunes, and cabbage. Macroconidia are sparingly produced on some of the media but microconidia are always present and usually in abundance.

That the production of spores is largely influenced by external conditions—insufficient nourishment, lack of moisture, high temperature, and reaction of the medium—was strongly brought out in the many cultures made.

The three first named conditions favor the production of spores, while the last may be so controlled as to be either favorable or unfavorable. Extremes in acids and alkalin reactions retard while those of less degree, such as favor good growth, are more or less favorable to the production of spores.

The effect of alkalis in cultures are more injurious than acids. Of the three alkalis used—potassium hydroxid, sodium hydroxid, and sodium carbonate—the two former are the most injurious. Growth is retarded by the presence of acid above certain small amounts, the strength depending largely on the kind used. Liquid media proved to be the most useful in determining such effects. Acids of the acetic series were found to be the most injurious, growth refusing to take place in strengths above +6.25 in a liquid medium, while those of the hydroxy acid group are least so, permitting growths in strengths of +25, and in some cases stronger.

On most media used a pigment varying in color from salmon to purple appeared in time, and was found to be artificially more or less controllable. It is retarded by weak solutions of alkalis and stronger solutions of acids, as a rule, altho weak strengths of malic, tartaric, citric, and lactic acids do under favorable conditions intensify colors, especially the salmon, pink, and red. High temperature, on the other hand, 29°C to 30°C, favors the production of color, particularly the reddish purple hues produced in the substratum. When a still higher temperature, as 35°C to 37°C, is used growth is seriously retarded and sometimes the fungus is killed. Color formation is largely favored by light, the salmon color increasing rapidly in the aerial mycelium of cultures kept in the dark for a time and then submitted to the action of the light.

*Fusarium II.***GROWTH ON
THE CORN**

The diseased portion of ears infected with this organism, as previously stated, have a deep pink to red color due to the pigment produced in the hyphae of the fungus. When the husks are removed the color is bright, especially in the most active stage of the organism. A microscopical examination reveals that the pigment is more or less irregularly distributed in the rather large mycelial threads, some cells being entirely without it.

Branching is moderately profuse and hyphal swellings are not rare. As yet no spores of any kind have been found on diseased ears, and for a time the organism was considered sterile and so reported at the Chicago meeting of the American Association for the Advancement of Science, January 1, 1908.* Later, however, spores were produced in culture, which placed the fungus in the genus *Fusarium*. The felty mass of mycelium permeates the inner husks and silk and holds them firmly to the ear. (Pl. II., Fig. 2). With age the red color fades. The kernels are brittle and the starchy contents is very powdery and considerably corroded by the action of the hyphae which permeate all portions of the grain. (Pl. XI., Fig. 7).

**GROWTH IN
CULTURE**

Fusarium II. was usually grown in petri dishes on various media and on modifications of the same ones to induce the formation of the reproductive bodies.

All stock cultures were made on boiled rice in test tubes and transfers of mycelium were made from these to the plates. A pure culture was first obtained from the interior of a sterilized diseased kernel of corn.

A series of cultures was carried on in plates duplicate to those used with *Diplodia*, the principal medium being extract of corn meal agar, to which various amounts of acids, alkalis, and carbohydrates were added.

The fungus grew rapidly on a number of these and in several cases soon produced the characteristic purplish-red color, but of more brilliant hues than occur on the infected corn.

In 4 days some growth had developed on all plates except the one containing formic acid +20 and on a starch medium containing Uschinsky's solution. The colonies on the media containing various sugars showed more rapid development and, at first, more color. Density of growth, however, was more pronounced in the plates containing tartaric, citric, and lactic acids, where branching was abundant and the colors white to orange. The colony in glucose culture was 2.5 inches in diameter at this time, the margin having a deep pink color while that of the central area was a bright red. Bladder-like swellings which gave rise to from 1 to 12 finger-like branches were numerous in the substratum. This condition existed to a greater or less extent in all plate cultures containing sugar.

Four days later, or 8 days after inoculation, there was no apparent growth in the cultures containing formic, acetic, butyric, and oxalic

* Barrett, James T., Science N. S. 27: 212.

acids, while in all others a more or less rapid increase in the amount of both submerged and aerial mycelium had taken place. The pigment in the malic, tartaric, citric, and lactic acid cultures varied in color from brilliant yellow to purplish red. Finally the resulting color became a rusty red to brown. The size of the colonies was still small but the growth was very dense. In most of the other cultures the colonies covered the plates.

For a time the growth still increased in many cultures and the colors grew more and more brilliant, then finally became dull and dingy.

Zonation was apparent in many cultures (Pl. IX., Fig. 2), becoming very marked in certain sugar media where it was due to alternate zones of profuse and sparse branchings and to hyphal swellings filled with coloring matter.

Alkaline cultures were for the most part colorless, but they eventually became a pale yellow often with slight traces of blue.

Twelve days after inoculation numerous small leather colored tufts were apparent on the surface of the growth in the lactic acid culture. A microscopical examination revealed them as masses of macroconidia of a fusarium type. (Pl. XI., Fig. 5). They were borne on short, much branched sporophores, and were fairly constant in size, measuring $50-62 \times 4.5 \times 6\mu$. Already many had swollen and some had germinated. After a careful search in all other cultures they were found in large numbers in but one and that the medium made by adding agar to Fermi's solution. This colony had the same color as that of the lactic acid culture and the tufts of spores were borne in the same manner.

Cultures made in Uschinsky's fluid variously neutralized gave different amounts of mycelium and numbers of spores. Macroconidia are produced rather abundantly in this fluid. Microconidia have not been found.

GERMINATION OF SPORES

Spores germinate readily, frequently very soon after having been cut off from the sporophore. In Uschinsky's fluid 90 percent germinated in 24 hours and some of the germ tubes were considerably branched. In 48 hours new spores had been produced and a few were beginning to germinate. In Raulin's fluid germination was very poor, and those that did produce germ tubes soon died. In distilled water the percentage of germinated was very good but subsequent growth very poor.

Fusarium III.

APPEARANCE ON EARS

The form of rot caused by this organism is less complete in its destructiveness of the ear than that of the other forms described. (Pl. III., Fig. 1). Many of the infected ears have only a few scattered diseased grains and, while such corn is almost valueless for marketing, it can be utilized for feeding purposes. Under certain conditions, however, most of the kernels may become diseased and the cob more or less infected.

The mycelium is white, very sparse, and is found principally in the ends of the kernels where it feeds upon the starch and produces large numbers of spores, mostly microconidia. In old dried specimens of corn the hyphae are more or less swollen and slightly constricted at the septa, and frequently contain many large globules. (Pl. XI., Fig. 10).

GROWTH IN CULTURE

On boiled rice growth is fairly rapid. The mycelium is moderately dense and almost immediately begins to produce spores and to have a faint pink to salmon color. The color never becomes very dense and with age fades somewhat. The hyphae are fairly constant in diameter in both cultures and on the corn, measuring about 4 to 5μ .

The spores vary considerably in size and are mostly one and two-celled, altho those possessing three cells are not rare on certain media. Microconidia range in size from $12-15 \times 3.5-5\mu$, while the macroconidia are $24-30 \times 35-5.5\mu$. (Pl. XI., Fig. 9).

On a plate of agar made from an extract of canned sweet corn, made +10 with hydrochloric acid, there was a fair growth in 2 days and some spores of both kinds had been produced. In one week the colony had become 1.5 inches in diameter, growth dense, all submerged, and a slight pink color had developed at the center. The protoplasm was very granular. The colony finally covered the entire plate. A little aerial growth developed at the center and a pink to red color was distributed thruout the plate.

In the same medium, made -10 with sodium hydroxid, growth was good from the beginning, becoming 1.5 inches in diameter in 4 days. Both kind of spores were abundant. The color remained white. Some of the hyphae were 5.5 to 6μ in diameter.

In the check plate, containing sweet corn extract agar alone, a rather rapid development took place and both types of spores were present in 2 days. The colony finally covered the plate and changed from a pale pink to a pale blue color.

Growth in cocoanut milk agar was very rapid and possessed more aerial mycelium than any of the above. The color was white dotted with pink tufts of spores. Some hyphal swellings developed and both kinds of spores were present. The growth became pale blue, and eventually deep purple in color.

In a few cultures on boiled rice there developed some small rather firm bodies of a pink and finally a rusty color, which resembled sclerotia. Some of these were sectioned in paraffin and were found to be made up of a mass of hyphae grown closely together. They were watched for some time but never came to maturity.

BACTERIA

The corn plant in the field is subject to attack by several kinds of bacteria, producing various forms of disease. The developing ears do not escape injury from this source, but the loss so caused seems to be small compared with that from the fungi heretofore described—almost

negligible from a practical standpoint. Whether these ear-infections are all due to the same species of bacteria has not been ascertained.

Certain ears when stripped of the husks show grains which are evidently diseased, rather uniformly distributed among the sound kernels or in small groups on some part of the ear. The diseased kernels are dark in color, often corroded upon the surface, and are brittle in texture. Sometimes a shiny, mucilaginous or gum-like exudate is noticeable upon the outer surface of the grains. Upon microscopical examination this exudate is found to be made up of a pure culture of a medium sized bacillus of short, cylindrical shape and capable of rapid ciliate movement. These are present in myriads and what appears to be the same organism is found in great numbers in the crumbling, starchy portions of the affected grains. A conspicuous characteristic of such diseased kernels is the red color taken on by the substance of the scutellum. When such grains are divided lengthwise thru the flat surfaces the starchy portion is seen to be distinctly white, while that known as the chit is as distinctly red.

The infection seems to begin externally with the silk and the bacteria follow a strand of this to its attached kernel, explaining how it comes about that any one of the latter upon the cob may be diseased among those adjoining healthy. Where these bacteria otherwise live has not been ascertained.

The bacteria of the growing corn plant is a subject well worth special study.

PREVENTION

The diseases of corn (maize) described in this Bulletin should not be confounded with corn smut which is frequently seen upon the ears as well as on other parts of the corn plant. This is easily recognized and is well known on account of the large outgrowths of a black or sooty substance which when dry readily falls into fine dust. The ear rots under discussion are very different and are best characterized as moldy in appearance. There is a white or pinkish, cobwebby, closely adherent growth on and in the husks, silk, grain, and cob or any of them. The affected ears are never perceptibly dusty, but later become brittle or friable and merit the name sometimes applied—dry rot.

The life history of the fungus (*Diplodia Zeae*) causing most of these ear rots (about 90 percent) has now been sufficiently worked out, as detailed above, to make it possible to recommend preventive measures with confidence in the prescriptions. This fungus lives as a parasite on the ears of the corn plant and apparently on no other portion of the plant. At first it was natural to suppose that a seasonal infection must be due to the wintering over on the old diseased ears, and that in all probability a careful collection of these at the time of husking would do much towards the reduction of the malady in the field the following year. This may be true to a considerable extent, but the discovery that the same fungus develops abundantly upon the dead stalks, even upon those that have lain on the ground two years and are therefore much decayed, changed materially conclusions upon

the subject. It will not be surprising if it is hereafter found that the fungus does sometimes live on other parts than ears of growing corn, neither is it impossible that it develops as a saprophyte on something besides corn stalks. It can be rather confidently asserted, however, that these things if true at all must be rare occurrences in Illinois corn fields, and that for practical purposes attention may be centered entirely upon the facts now made known.

Little dependence can be placed upon any direct treatment of the soil, any outward application to the plant, any variation in time of planting, any selection of varieties, or other similar matters, tho there may be some difference at different times and under special conditions on account of any such variations connected with the soil or with the plant. A few cases, indeed, have been observed where the amount of rot was undoubtedly traceable to some such difference, now one thing, now another. But there is not enough of this to alter the recommendations that can now be made.

It is best then to give attention principally if not solely to the active agent which causes the destruction. Rot does not occur, as has been shown, under any circumstances or condition except as it is directly brought about by the fungus, and the fungus cannot start except by its own reproductive methods. Keep the spores away from the green ears and the corn will remain sound. Keep the fields free from the substance on which spores are produced from the beginning of a season for infection, and the crop must remain free from danger in this regard.

Undoubtedly there is some dissemination of spores from the earlier affected ears to sound ones of the same season, but here again the probable amount of loss so caused is small. Practically the new infection *comes from the old stalks*—those one and two years old—and therefore these must have chief attention in the combat. From this it is easy to see what procedure should be adopted in trying to reduce the rot in, or eliminate it from, the field. Stated in a word, it is carefully to take out of the field and destroy the rot-infected ears at the time of husking, with the view of reducing the amount of the fungus later on the stalks; then to remove from badly infected fields the stalks by low cutting and hauling away or by burning, or better still by such rotation of crops that corn shall not follow corn within a period of two years. Care should also be taken not to plant corn by the side of an old infected field especially if the latter is upon the side from which come the prevailing summer winds—the south and west.

As corn is commonly cut for fodder or for silage, there may be stumps enough left to carry over too much of the disease, and old stalks may get back again with the manure to a detrimental extent; tho by attention to these matters there must be a possibility of causing a decided diminution of the trouble by such early removal of the stalks.

Unless the old stalks with their harboring fungus are effectually destroyed, corn should not be planted again where there has been much

of the disease for two years thereafter, nor nearer than 20 to 30 rods, especially on the windward side, of an old corn field badly infected one or two years before.

HISTORY AND SYNONOMY (DIPLODIA ONLY)

Schweinitz in his *Synopsis Fungorum Carolinae* (1822), number 79y described a fungus found on old stalks of maize which he called *Sphaeria Zeae*. Later in his *Synopsis Fungorum in America Boreali*, [North American Fungi] page 207, number 1451, he again described the same fungus on the same plant under the same name as follows:

"Omnino tecta, epidermide fusco tincta (ostiolis solis prominulis) satis elevata. Seriatim disposita, brevis, utrinque acuminata, subconfluens. Perithecia binis vel ternis tantum in caespitulo, subdistantibus, primum albofarctis, demum evacuatis. Ostiolis latis, umbilicatis, saepe unico."

This may be translated as follows:

Entirely covered, epidermis fuscous colored, rather elevated (ostiola alone a little prominent). Distributed in series, short, acuminate at both ends, subconfluent. Perithecia only two or three in a group, subdistant, at first white within, at length evacuated. Ostiola broad, umbilicate, often to a marked degree.

In the latter work, under number 1866, the author refers to number 234 of *Synopsis Fungorum Carolinae*, and classifies what seems to be the same fungus as *Dothidea Zeae*, but there is no mention in either case of asci. This was before the day of the compound microscope as a serviceable instrument, which sufficiently accounts for the absence of finer details in the descriptions.

In 1847 Berkeley, in Hooker's *London Journal of Botany* 6:326 described a fungus from the stalks of maize which he called *Sphaeria Maydis*, and appended the following description quoted in Ellis and Everhart, *North American Pyrenomycetes* page 452:

"Spots minute, elevated, often purple-brown, punctiform or subelliptical, rarely linear, containing very few perithecia, with a single, broad-conical ostium. Sporidia oblong, slightly curved, uniseptate. Habit that of *Leptosphaeria arundinacea*. Very different from *Sphaeria* (*Diplodia*) *Zeae*, Schw."

These descriptions seem to characterize different species and apparently justify the remark by Berkeley that the fungus at the time in his hands was very different from that earlier described by Schweinitz.

But, probably more from this remark than from anything else, most subsequent writers have referred the fungus observed by many on old stalks of corn and identified as a *Diplodia* to Berkeley's species. Thus Saccardo, in *Sylloge Fungorum*, 3: 373, (1884), writes *Diplodia Maydis* (Berk.) Sacc., and quotes *Sphaeria Maydis* Berk., *Lond. Jour. of Bot.* 6:326, as a synonym, together with in the same way, *Diplodia Zeae* Lév., *Ann. Sc. Nat.* III. 9: 258, and *Sphaeria Zeae* Curr., *Simple Sphaer.* n. 358, f. 128. So far as these references are concerned, Saccardo properly takes Berkeley's name, for this was published in 1847 while the dates for the others are respectively 1848 and 1859. Lévillé however founded his name upon *Sphaeria Zeae* Schw., which, as shown above, dates back to 1822. If, therefore, the plant so called is the same as that named by Berkeley *Sphaeria Maydis*, the latter name becomes a synonym. Notwithstanding the statement by Berke-

ley that the two plants are very different, there is now much reason to suppose they are really the same, or at least that specific distinction cannot be maintained. The reference by Saccardo to Currey is based upon a paper by the latter in the Trans. Linn. Soc. 22:330 (Simple Sphaer.) appearing in 1859 upon the fungi in the Hooker Herbarium—this particular material undoubtedly coming from America and probably collected by Schweinitz. Though finding no asci, Currey retains the genus relation and identifies the specimens as *Sphaeria Zeae* Schw. The spores as figured (Pl. 59, f. 128) agree very well with those of our plant. Moreover reference is made to Fries, Sys. Fung. 2:527 where *S. Zeae* Schw. is referred to (1823). This can, therefore, be none other than the Schweinitzian plant, and if, as Saccardo thinks, the name is a synonym of *S. Maydis* Berk. the two names must apply to the same species.

The exsiccati specimens examined show no differences which should indicate specific distinctness. These are:

Diplodia Zeae Schw.

Ravenel, Fung. Car. n. 74 (1852)

Diplodia Zeae Lév.

Sphaeria Zeae Schw.

Thümen, Myc. Univ. n. 1194 (1878)

Diplodia Zeae Lév.

Ellis, N. A. Fungi n. 31 (1878)

Diplodia Zeae (Schw.)

Ravenel, Fung. Amer. n. 393 (1879)

Diplodia Maydis (Berk.) Sacc.

Roumeguère, Fung. Gall. n. 5378 (1890)

Diplodia Zeae Lév.

Ellis and Everhart Fung. Col. n. 73 (1893)

Ellis and Everhart, N. A. Pyr. 745 say:

"The spec. in Herb. Schw. is the same as *Diplodia Zeae* Lév. in Ell. N. A. F. n. 31".

Assuming that *Sphaeria Maydis* Berk. is the same as *Sphaeria Zeae* Schw., or that the former name really applies to some other plant than that with which we are dealing, there can be no reasonable doubt that the fungus described in this Bulletin should be called *Diplodia Zeae* (Schw.) Lév., until this form is proved to be genetically connected with something of higher fruiting. Many surmises of the latter kind have been made; Schweinitz himself made it a species of *Sphaeria* and was followed in this by Berkeley and Currey as noted above. The former also identified another specimen as a *Dothidea* (Syn. Fung. Bor. n. 230 (1866) which he subsequently (Am. Sc. Nat. III. 9:258) admitted to be the same as the one called *Sphaeria*. Later the name, *Sphaeria Maydis* Berk. has several times been applied to American specimens certainly identical with our plant. Bennett, Cat. Pl. R. I. 87, (1888), places it in *Dothiora*, and Ellis and Everhart, N. A. Pyr. 452, (1892), assigns it to *Diaporthe*. But there is no evidence that these writers had before them perithecia with asci or that they had

anything more than is usually to be found in the examination of ordinary specimens. There is no proof known to the present writers that a mature or ascus stage exists, though there are such forms not infrequently associated with the *Diplodia* on old culms of maize. Our cultures of the latter though both varied and prolonged have not demonstrated further fruiting. *Diaporthe incongrua* E. & E., and *D. Kellermanniana* Winter, are both (if they are distinct) found on decaying culms of *Zea Mays*, N. A. Pyr. 453.

The first suggestion in print that this fungus works as a parasite seems to be the Heald, Science, N. S. 23:624 (1906), where the following note, under the title, "New and Little-known Plant Diseases in Nebraska," is given:

"Moldy corn due to a fungus provisionally referred to *Diplodia Maydis*, but differing in several points in habit and structure."

One of us, Barrett, Science N. S. 27:212-213 (1908), describes under "Dry Rot of Corn and Its Causes" something of the effects of *Diplodia*, "very probably *Diplodia Maydis*", as a parasite upon corn and briefly relates its life history. Further citation upon the same is, Burrill and Barrett, Circ. Ill. Ag. Sta. n. 117:1-3, (1908). Here, too, mention is made of similar rots due to species of *Fusarium* and by bacteria.

Heald, Wilcox and Pool, Reprint from the Twenty-second Annual Report of the Nebraska Agricultural Experiment Station, distributed January 1, 1909, give a good description of the fungus, called by them *Diplodia Zeae* (Schw.) Lév., and of its work as a parasite upon corn. Excellent plates accompany the text.

The fungus must for the present be cited under the genus *Diplodia* and the synonymy seems to be as follows:

- Diplodia Zeae* (Schw.) Lév.
- Sphaeria Zeae* Schw. 1828
- Dothidea Zeae* Schw. 1831
- Sphaeria Maydis* Berk. 1847
- Diplodia Zeae* (Schw.) Lév. 1848
- Diplodia Maydis* (Berk.) Sacc. 1884
- Dothiora Zeae* (Schw.) *Bennett 1888
- Diaporthe Maydis* (Berk.) Ell. and Ev. 1892

Thru the courtesy of Dr. Farlow, Mr. A. B. Seymour examined, in the collections of the former, certain of the specimens enumerated above; and gave from the notes, prepared for publication otherwise, citations to literature embracing all the above names. From these notes, Mr. Seymour arranged the synonymy as it is above. This latter was communicated in a letter dated July 30, 1908.

It should be said that the manuscript for this Bulletin was practically completed during August, 1908, but was not sent to the printer until February 8, 1909.

* Bennett wrote: *Dothiora Zeae* Lév.

DESCRIPTION OF PLATES

Plate I. Fig. 1.—An ear of sweet corn thirteen days after inoculating in the tip with spores of *Diplodia Zeae*. Fig. 2.—Another ear of the same, inoculation at base.

Plate II. Fig. 1.—An ear of corn infected with *Fusarium I*. Fig. 2.—An ear of corn showing the effect of *Fusarium II*.

Plate III. Fig. 1.—Field corn with scattered individual kernels infected with *Fusarium III*. Fig. 2.—A longitudinal section of an ear of corn showing the small, black pycnidia in the cob toward the outside.

Plate IV. Fig. 1.—An ear of sweet corn destroyed by *Diplodia Zeae*, spores of which were inserted into the shank bearing the ear. Fig. 2.—Ear of sweet corn artificially inoculated and photographed after being in the laboratory seven days. The black color about the base of the ear is due to numerous pycnidia.

Plate V.—Two shanks of the corn plant bearing numerous pycnidia of *Diplodia Zeae* as small black specks. These shanks were collected in the spring.

Plate VI. Fig. 1.—A piece of old corn stalk showing pycnidia of *Diplodia Zeae*. Fig. 2.—Piece from the same stalk as Fig. 1 after soaking in water fifteen hours and keeping moist for a few days in a damp chamber. The black masses are tendrils of *Diplodia* spores. Fig. 3.—A single pycnidium of *Diplodia Zeae* on a corn stalk showing the exuded tendril of spores and the internal cavity.

Plate VII. Fig. 1.—A cross section of an ear of corn showing *Diplodia* pycnidia as black specks in the cob. Fig. 2.—A photograph of germinating spores of *Diplodia Zeae*.

Plate VIII. Fig. 1.—A photomicrograph of *Diplodia* spores from an ear of diseased corn. Fig. 2.—*Diplodia* spores from a rice tube culture.

Plate IX. Fig. 1.—A petri dish containing corn meal extract agar and 5 percent galactose in which are imbedded numerous pycnidia of *Diplodia Zeae*. Fig. 2.—A sweet corn agar plate showing zonation of *Fusarium II*.

Plate X. Fig. 1.—A cross section of a pycnidium of *Diplodia Zeae* on a corn stalk. Fig. 2.—A cross section of a pycnidium of *Diplodia Zeae* on a kernel of corn.

Plate XI. Fig. 1.—Spores of *Diplodia* from corn. Fig. 2.—Young spores with sporophores attached. Fig. 3.—Germinating *Diplodia* spores. Fig. 4.—Short, more or less swollen, and darkened branches of *Diplodia* hyphae. This indicate the beginning of pycnidia formation. Fig. 5.—Macroconidia of *Fusarium II*., some of which are beginning to germinate. Fig. 6.—Mycelium of the same fungus. Fig. 7.—Starch grains from a corn kernel infected with *Fusarium II*., showing the corrosive effect. Fig. 8.—Sporophores of

All drawings and photographs were made by James T. Barrett except Plate I., which was executed in colors by Mrs. Flora M. Sims. (The reproduction as Plate 1 is not in color, but a colored duplicate accompanies a part of the issue).

Fusarium II., drawn at 11:30 a. m. and at 1:30 p. m. to show the rate of development of the spores in culture. Fig. 9.—Microconidia and macroconidia of *Fusarium III.* from culture. Fig. 10.—Mycelium of the same from a corn kernel. Fig. 11.—Microconidia and macroconidia of *Fusarium I.* from a prune agar plate. Fig. 12.—Same from an infected ear of corn. Fig. 13.—A spore-producing hypha from a young prune juice culture. Fig. 14.—Germinating spores of *Fusarium I.* Fig. 15.—Spores of *Fusarium I.* from a dried, diseased embryo ear of corn. Fig. 16.—A hyphal branch of *Fusarium I.* producing both microconidia and macroconidia.



PLATE I.



FIGURE 1. INOCULATED IN THE SILK
WITH DIPLODIA.

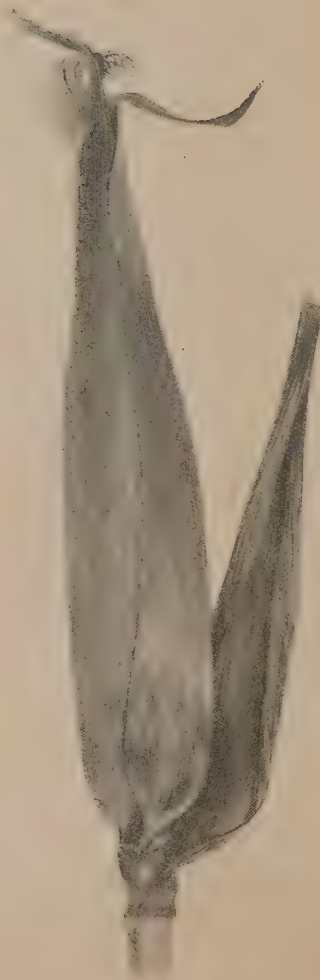


FIGURE 2. INOCULATED AT THE BASE
WITH DIPLODIA.

PLATE II.



FIGURE 1. FUSARIUM I.

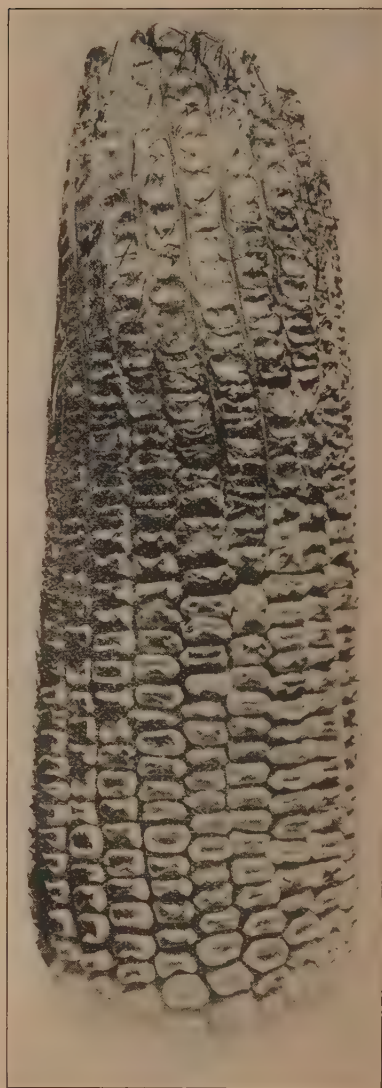


FIGURE 2. FUSARIUM II.

PLATE III.



FIGURE 1. FUSARIUM III.

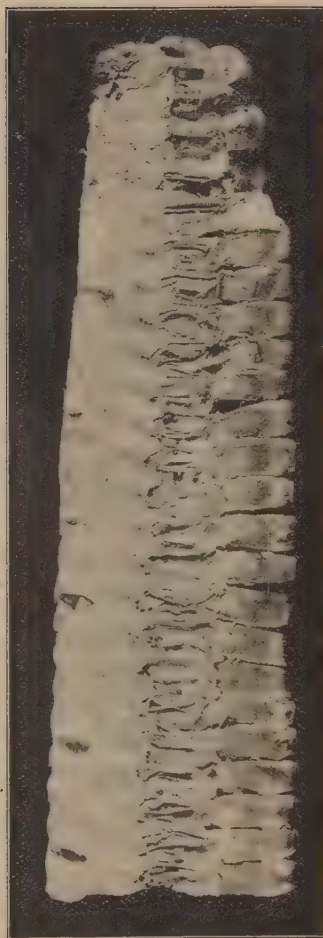


FIGURE 2. DIPLODIA.



FIGURE 1. DIPLODIA.



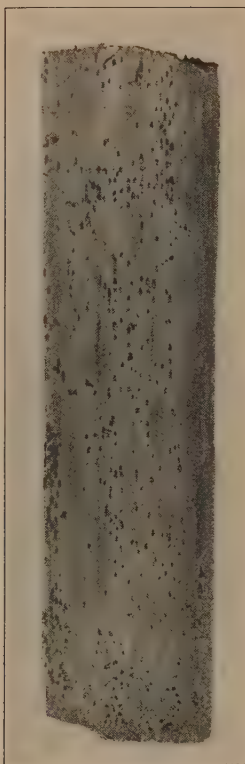
FIGURE 2. DIPLODIA.

PLATE V.



✓ DIPLODIA ON OLD SHANKS.

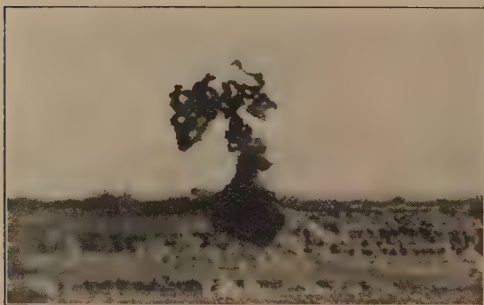
1



2

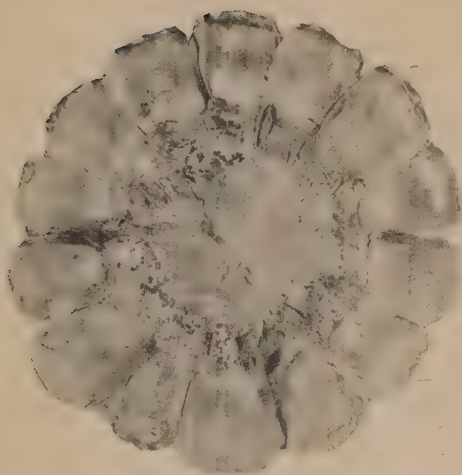


3

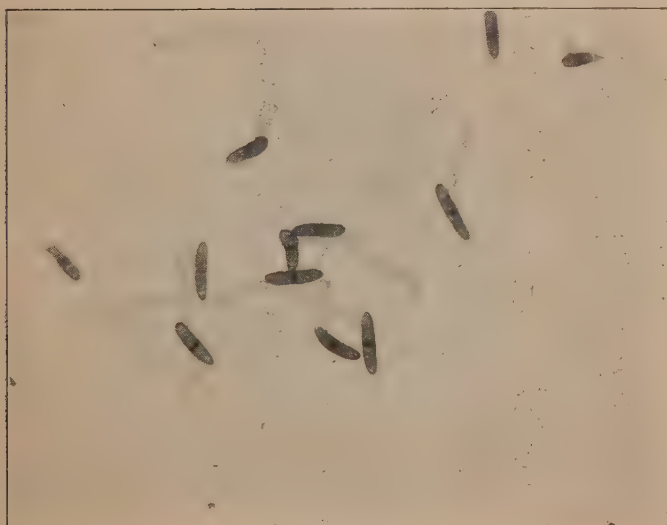


DIPLODIA ON OLD STALKS. FIGURE 1, DRY. FIGURE 2, AFTER KEEPING MOIST.
FIGURE 3, EXUDING SPORES (MAGNIFIED).

PLATE VII.



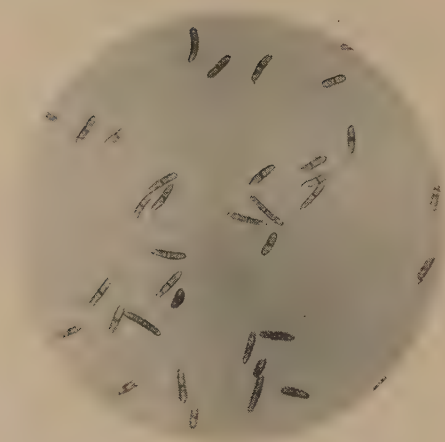
1



2

DIPLODIA. FIGURE 1, PYCNIDIA ON COB. FIGURE 2, GERMINATING SPORES.

PLATE VIII.



1



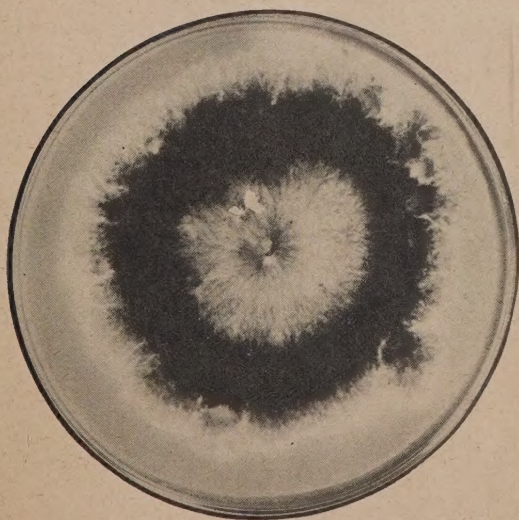
2

DIPLODIA SPORES. FIGURE 1, FROM DISEASED EAR. FIGURE 2, FROM A CULTURE.

PLATE IX.

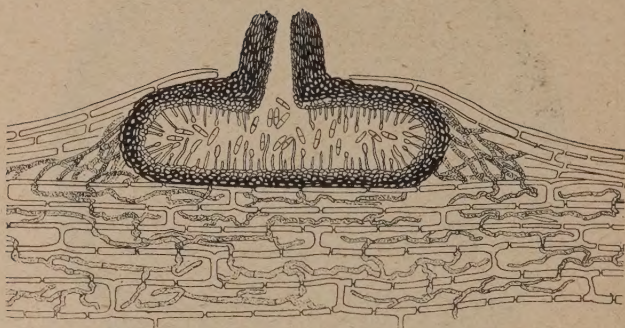


1

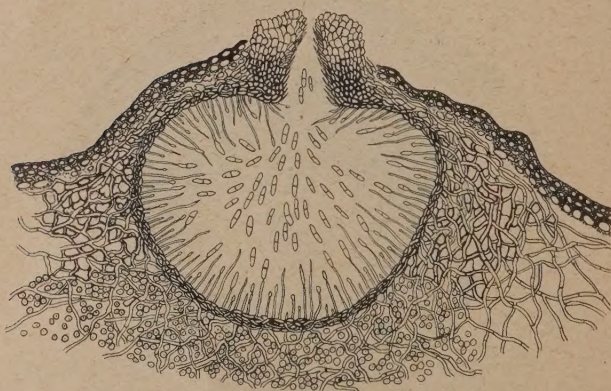


2

FIGURE 1, DIPLODIA CULTURE SHOWING PYCNIDIA. FIGURE 2, FUSARIUM II.
CULTURE SHOWING ZONATION.



1



2

PYCNIDIA OF DIPLODIA: FIGURE 1, FROM STALK. FIGURE 2, FROM CORN KERNEL.

PLATE XI.



J.T.B. del.

SPORES, ETC.: FIGURES 1 TO 4, *DIPLODIA*; THE OTHERS *FUSARIUM*.

